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PROBLEMS AND SOLUTION OF ENVIRONMENTAL NOISE AT INDUSMIN LTD., MIDLAND, ONTARIO

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PROBLEMS AND SOLUTION OF ENVIRONMENTAL NOISE AT INDUSMIN LTD., MIDLAND, ONTARIO

by

M.U. Savich*

ABSTRACT

The high level of noise coming from the plant of Indusmin's Ontario Silica Division in Midland has created a community environmental problem (56 to 59 dBA).

Preliminary measurements have demonstrated that the noise level about the plant can be decreased by an insulation of the plant and an enlargement of the green belt around its boundaries. The key to a solution lies in a close rapport and cooperation between the Company and Midland City Hall.

In their dialogue, Indusmin Ltd., City Hall and the Ontario Government should all take the following facts into account.

- because Canada now imports much silica, and Ontario needs more silica than the Province is producing, it is reasonable to expect an increase in production capacity at Midland to take effect in the near future;
- silica production is responsible for thousands of jobs in Ontario, and many more throughout Canada.
- although the Midland location constitutes prime land for Ontario industries, it is also a popular tourist area. Since it is not desired to develop industry at the expense of tourism, and all its economic benefits, the community environmental problem should be addressed immediately.

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PROBLÈMES DU BRUIT PRODUIT PAR L'INDUSMIN LTD, À MIDLAND, EN ONTARIO ET SOLUTIONS

Par

M.U. Savich*

RÉSUMÉ

Le bruit venant de l'usine de Midland de la Division de la silice d'Indusmin, en Ontario, a créé un problème environnemental dans cette collectivité (56 à 59 dBA).

Des mesures préliminaires indiquent que le bruit autour de l'usine pourrait diminuer si l'usine était mieux isolée et si la zone de verdure qui l'entoure était agrandie. La seule solution réside donc dans une collaboration étroite entre la société et la municipalité de Midland.

Dans leurs discussions, Indusmin Ltd, la ville de Midland et le gouvernement de l'Ontario devraient tenir compte des facteurs suivants:

- comme le Canada importe beaucoup de silice et que les besoins de l'Ontario sont supérieurs à sa production, il est raisonnable de prévoir, dans une avenir rapproché, une augmentation de la capacité de production de l'usine de Midland;

- bien que Midland soit un emplacement privilégié pour les industries ontariennes, c'est aussi une région touristique; il ne serait donc pas souhaitable de laisser l'industrie se développer aux dépends du tourisme et des avantages économiques qui en découlent. Il faut donc régler ce problème d'environnement immédiatement;

- des milliers de travailleurs ontariens et beaucoup plus de Canadiens travaillent dans le secteur des produits de la silice.

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INTRODUCTION

On a geological map of Ontario, one can see that the rock, south of a line extending from Midland to Kingston and the eastern tip of Ottawa, is of a Paleozoic sedimentary formation. The sand, gravel and clay now covering much of Southern Ontario was deposited over four ice ages, the most recent of which was about 10,000 years ago (1). Glaciers in the north eroded Precambrian rocks containing metalic minerals and deposited potential building materials in the south, where 90% of Ontario's population now lives and uses them.

Silica (SiO_2), of Precambrian age, is one of the most common minerals. Commercial sources are restricted to pure sands, sandstone quartzites, and vein quartz. Silica, however, has a low unit value. For a deposit to be economically viable it should be mineable by low cost methods and, so as to minimize transportation costs, should be close to the consuming areas.

Indusmin Ltd., a member of the Falconbridge group of Companies, quarries a high-grade silica deposit of pure Precambrian Lorraine quartzite on Badgeley Island in Georgian Bay. A primary crushing plant at the deposit site, some 190 km north of Midland, and a grinding and processing plant in Midland, came on-stream in 1970 (Fig. 1). The Badgeley Island operation has a capacity of approximately 1 million tons per year. Primary products from the crushing plant on the island are shipped directly to manufacturers of ferro-silicon, which is applied in various metallurgical processes. Products are also shipped to the Midland grinding plant, which has a capacity of about 500,000 tons per year, where refined silica products are made (2).

Use of high-purity silica sand is widespread. It is the basic constituent of glass and is used as a metallurgical flux. It is also used in: the manufacture of silicon carbide, which is used as an ore of silicon and ferrosilicon; as foundry sand for metal casting; in sand casting; as filler

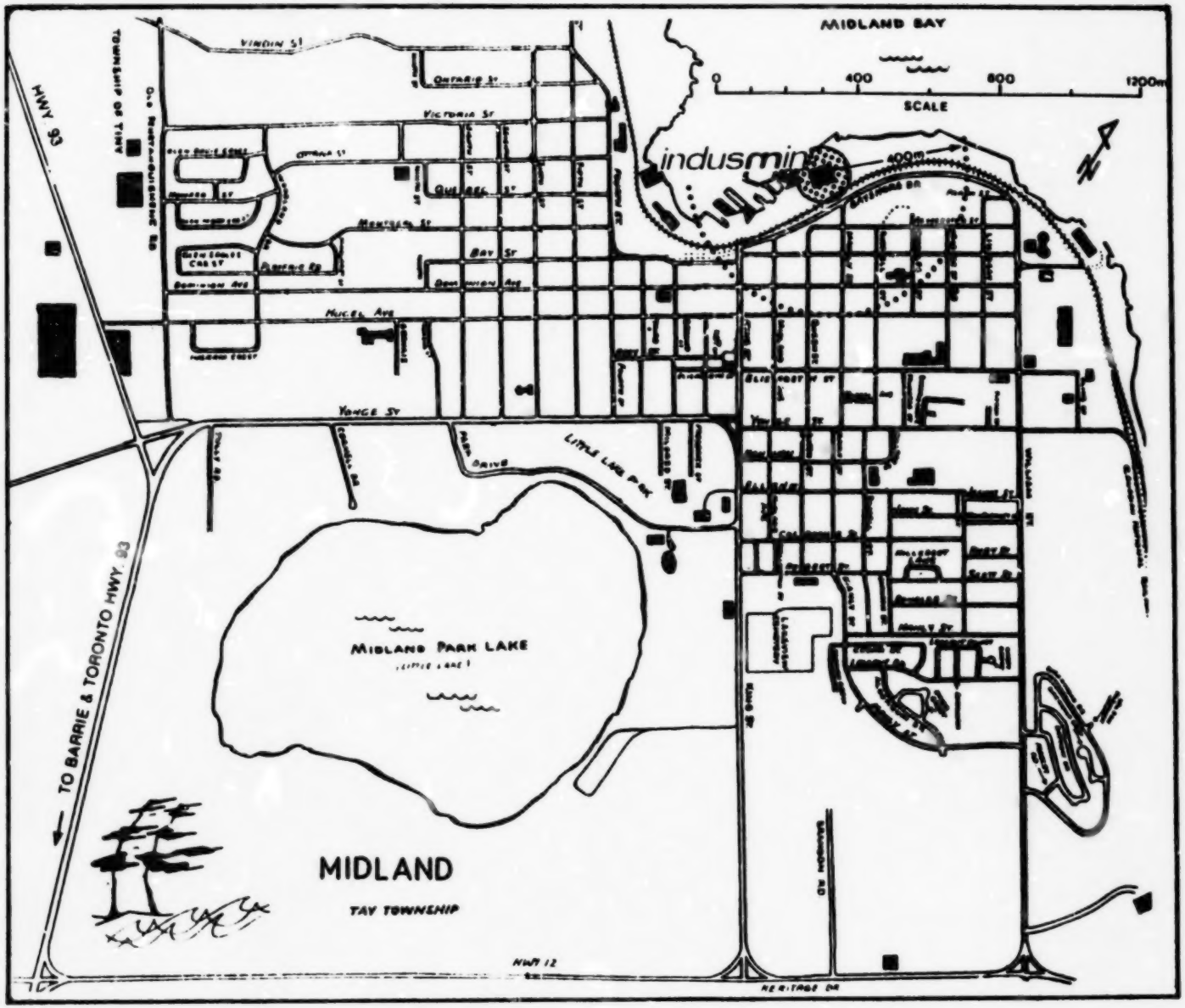


Fig. 1 - Location of Indusmin's plant in Midland.

in tiles and asbestos cement pipes; for fibreglass insulation; and, light concrete and bricks ('Siporex'). The diverse list of products is almost endless (3).

After short analysis, it can be concluded that the location of Indusmin in Midland is appropriate for three reasons:

1. The grinding and processing plant at Midland is close to a consumer area (distance from Midland to Toronto is 143 km).
2. A good highway exists and there are railway connections to the plant.
3. The plant employs people directly from Midland, and, indirectly thousands across Ontario in industries ranging from metallurgy to construction.

With the construction of Indusmin's Ontario Silica Division in Midland, a community environmental problem arose due to the high level of noise coming from the plant. Preliminary measurements have demonstrated that the noise level around the plant can be decreased.

MILL NOISE - SCREENING AND GRINDING BUILDING

Octave band frequency noise measurements of the screening and grinding plant have been re-evaluated (Table 1). Three different evaluations of the results have been made:

1. dBA evaluation over frequencies of 31.5 Hz to 125 Hz; which have no bearing on the final result;
2. dBA evaluation over frequencies of 31.5 Hz to 250 Hz; which have a minor bearing on the final result; and
3. dBA evaluation over frequencies of 250 Hz to 8 kHz; which yields almost the same result as dBA estimated over all frequencies.

Table 1 - Frequency spectrum of noise at the screening and grinding building (4).

No.	Location	Frequency (Hz)									dBA				
		31.5	63	125	250	500	1k	2k	4k	8k	Mea'd	Est'd	250 Hz to 8 kHz	31.5 Hz to 250 Hz	31.5 Hz to 125 Hz
1	Primary Mill Room	105.5	98	102.5	107	110.5	112.5	111.5	106.5	96	116.5	116.7	116.7	98.3	86.7
2	Steel Mill Fan	105.5	102	104.5	97	96	91.5	87.5	81	72.5	97.5	97.9	97.4	91.2	88.3
3	Steel Mill	103	97	98.5	100.5	101	98.5	94.5	87.5	79.5	102.5	102.7	102.6	92.1	82.9
4	Mill MCC	89	82	84	80.5	77.5	79.5	80.5	70.5	63.5	84.5	84.7	84.6	73.2	68.3
5	Mill Workshop	90	83.5	81.5	78.5	82.	79	74.5	69.5	61.5	82.5	83.4	83.3	71.2	66.3
6	Silex Mill	97.5	91.5	101	99	100.5	97.5	93	89.5	82	101	102.1	102	91.2	85.1
7	Silex Mill Fan	101.5	97	105.5	101.5	98.5	94	86.5	81.5	72.5	99.5	99.8	99.3	94.3	89.6
8	Primary Fan	104.5	97.5	97.5	96.5	94.5	90.5	84.5	79.0	72.5	94.5	95	94.8	88.6	82
9	2nd Floor Outside Control Rm.	97.5	91	91.5	89.5	89.5	86.5	81.5	75.5	64.5	90.5	91	90.9	81.8	75.9
10	Mill Control Room	88.5	81.5	76.5	73.5	71	68.5	62.5	54.5	48	73	73.1	72.8	66.4	62
11	Maint. Foreman's Office	93	85.5	88.5	77.5	71.5	65.5	62.5	53.5	42	75	75.9	73.1	74.1	72.7
12	3rd Floor Blowers	102	95.5	88.5	85.5	86	83.5	79.5	74.5	66.5	87.5	87.9	87.9	78.7	74.6
13	3rd Floor Above Primary Mill	107.5	97.5	90	87.5	87.5	85.5	82.5	75.5	66.5	89.5	89.9	89.9	80.7	76.7
14	Tyler Screen	111.7	103.2	90	89	88.7	88.2	83	79.3	74.3	91.8	92.1	91.8	82.9	79.8
	: South	105.5	96	87	88.5	88.5	87.5	82.5	77.5	70.5	90.5	(91.3	91.2	79.5	74.3)
	: Central	116	109	91	90.5	89.5	89.5	84	80.5	76	93.5	(93.5	92.9	86.3	84.5)
	: North	113.5	104.5	92	88	88	87.5	82.5	80	76.5	91.5	(91.7	91.3	83.4	81.4)
15	Sweco Room 4th Floor: outside	109.5	101	86.5	86.5	86.5	85.5	81.5	79.5	76.5	89.9	(90.1	89.8	80.4	77.3)
	: inside	102	93.5	96	91.5	94.5	97.5	97.5	97	95.5	103.5	103.7	103.7	84.5	80.3
16	Sweco Room 5th Floor: outside	100	91	92.5	83.5	84.5	84.5	82.5	81	78.5	89.5	(89.7	89.5	78.9	76.9)
	: inside	100	92	94	94.5	96.5	98	97.5	96.5	96	103.5	103.9	103.9	86.3	78.3
17	5th Floor: Central	99	91.5	89.5	86.5	85.5	86.5	82.5	81.5	76.5	90.5	90.6	90.5	79.2	74.3
18	4th Floor Blower	99	91	89.5	85.5	89.5	87.5	85.5	83.5	70.5	92	92.6	92.5	78.5	74.2
19	# 16 Conveyor Gallery	91	82.5	85.5	82.5	84.5	82.5	78.5	72.5	64.5	86.5	86.7	86.6	75	69.8
20	Top of Flour Silos	90	92.5	91.5	89.5	95.5	95.5	95	86.5	80.5	99.5	100.1	100	82.4	77.8
21	Top of Sand Silo	91	84.5	97.5	85.5	91.5	90.5	89.5	87.5	83.5	96.5	96	95.9	82.7	81.5
22	7th Floor	89.5	83.5	88.5	83.5	85	80.5	79	76.5	64.5	86	86.8	86.6	76.7	72.7
23	8th Floor	93	86	87.5	84.5	84.5	82.5	79.5	75	65.5	87.5	87.2	87.1	77.1	71.9
												Mean	91.01	92.78	82.05	77.01
												Std. Dev.	9.8	10.05	7.95	7.07

Note: ( ) not estimated

In the final evaluation (mean and standard deviation), measurements at the No. 14 Tyler screens South, Central and North locations were not taken into account. Only the mean for the Tyler screen locations was used. Also, not taken into account were measurement results for No. 15 Sweco Room, 4th floor (outside), and No. 16 Sweco Room, 5th floor (outside). Final results show that estimated 93.03 ± 9.8 dBA is almost equal to the estimated range of 250 Hz to 8 kHz - 92.78 ± 10.05. In order to clarify the situation in the Screening and Grinding Building, a frequency spectrum graph of noise was constructed (Fig. 2). From this graph it is evident that the highest noise level is in the Primary Mill Room. This means that it is one of the most hazardous sources of noise, especially since noise over the audible frequency range is very high (at 1 kHz it is about 113 dBA).

Another important aspect is the noise spectrum in the maintenance foreman's office and mill control room. The conspicuous slope over all frequencies proves that noise from 150 Hz to 8 kHz can be successfully decreased. In the maintenance foreman's office, only frequencies of 31.5 Hz and 63 Hz show no marked decrease in noise. This means that more effective insulation should be placed in strategic locations, insulation which would decrease noise to an acceptable minimum outside the mill. It should be underscored that such a task is not an easy one, where in a relatively small space, 23 blowers, 16 fans, grinders and screens are installed. Those who have worked in these, or similar industries in silicate or asbestos, know that every machine enclosure is unwelcome because unseen leakages occur when abrasion creates holes. Appropriate measures should then be taken immediately as there is a threat of creating a more difficult and dangerous environment - one of dust pollution.

DRYING BUILDING, FLOUR AND LOADER

The same re-evaluation of measurement results was done in the case of

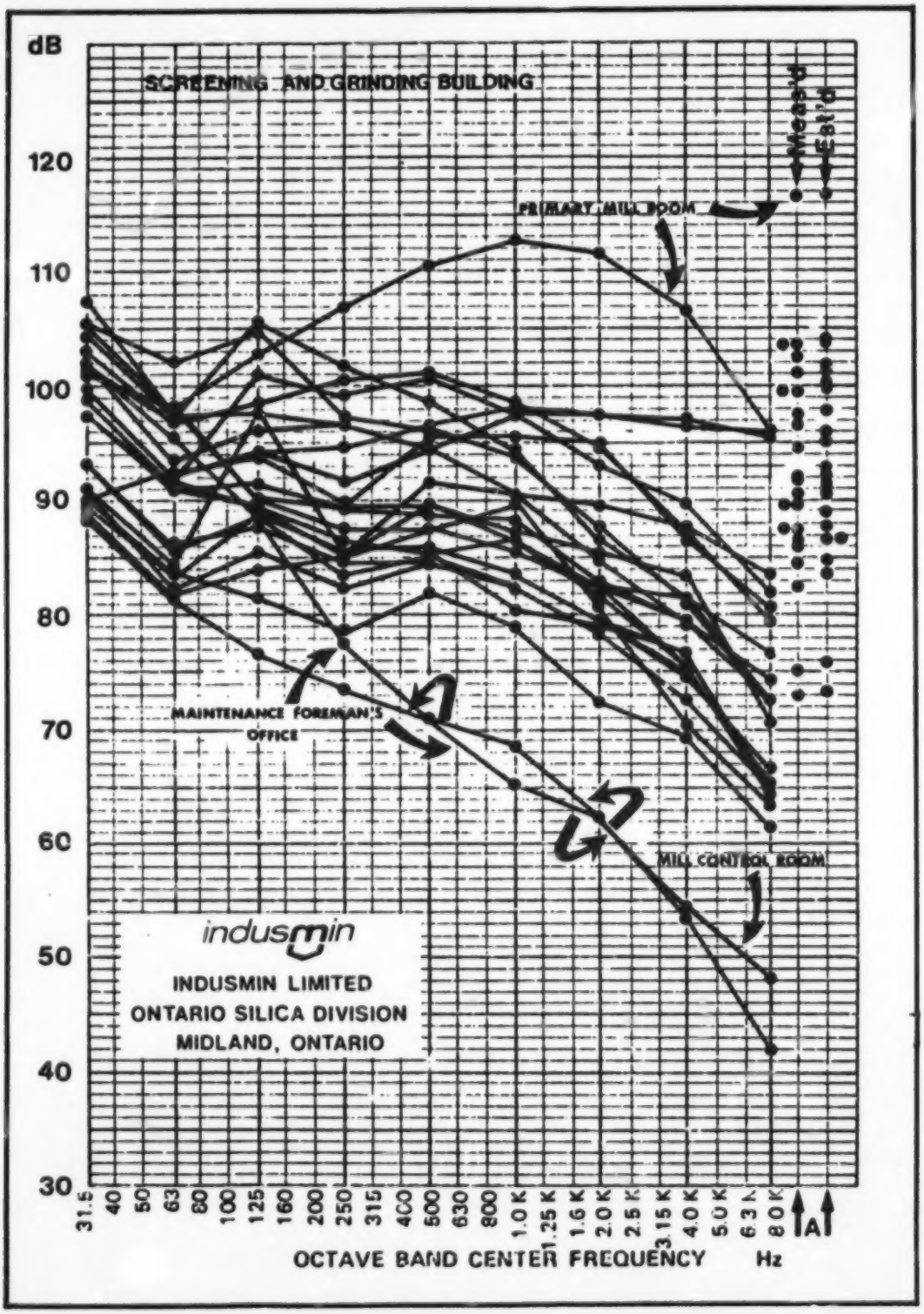


Fig. 2 - Frequency spectrum graph of noise at the screening and grinding building. The acoustic energies over the audible frequency range (250 Hz to 2000 Hz) are not equal.

Table 2 - Frequency spectrum of noise at the drying building, flour and loader (4).

Drying Building

No.	Location	Frequency (Hz)									dBA				
		31.5	63	125	250	500	1k	2k	4k	8k	Meas'd	Est'd	250 Hz to 8 kHz	31.5 Hz to 250 Hz	31.5 Hz to 125 Hz
1	MCC	82.5	78	90	86	79.5	73.5	65.5	57.5	50.5	80	81.7	80.9	78.8	74
2	Blowers	89	90	95.5	95.5	96.5	99	96	91.5	82.5	102.5	102.5	102.4	87.3	79.6
3	Dryer	89	88	93.5	94.5	98	101	100.5	97.5	92.5	104.5	105.9	105.9	86.2	77.7
4	Combustion Chamber Fan	93	98.5	95.5	105	101	87.5	94.5	90.5	82.5	102.5	102.1	102	96.1	80.3
5	Crusher	93	89	96	98.5	101.5	101.5	96.5	91.5	82.5	103.5	104.7	104.7	90	80.1
6	Control Booth: outside	89	88	88.5	93.5	95.5	97.5	94.5	89.5	81.5	101.5	101.5	101.5	84.8	72.9
	: inside	86	80	81.5	74.5	65.5	59.5	59.5	55.5	43.5	69.5	70.9	69.4	68.7	65.8
7	Tyrock Screen	94.5	90	96.5	93.5	92.5	92	89.5	85.5	80	96.5	96.9	96.4	86	80.6
Note: ( ) not estimated.											Mean	94.91	94.53	84.73	76.87
											Std. Dev.	13.41	13.97	8.75	5.40

Flour

No.	Location	Frequency (Hz)									dBA				
		31.5	63	125	250	500	1k	2k	4k	8k	Meas'd	Est'd	250 Hz to 8 kHz	31.5 Hz to 250 Hz	31.5 Hz to 125 Hz
1	Load Out Station (operation position)	88	82.5	94	91.5	92.5	89	88.5	85.5	74.5	95.5	95.2	95	81.8	78
2	Airslide Blower (2nd Floor)	85.5	83	89	91.5	98.5	94.5	95.5	96.5	87.5	101.5	102.3	102.3	83	73.1
3	Under Flour Silo	83.5	79	86.5	86.5	87.5	83.5	77.5	70	64.5	86.5	88.2	88.1	78.3	70.6
4	Hour Silo Airslide Blower Room	75.5	87.5	108	109.5	113	103	95.5	90.5	90	112.5	111.4	111.4	101.1	92
											Mean	99.28	99.2	86.55	78.43
											Std. Dev.	9.92	9.99	10	9.56

Loader

No.	Location	Frequency (Hz)									dBA				
		31.5	63	125	250	500	1k	2k	4k	8k	Meas'd	Est'd	250 Hz to 8 kHz	31.5 Hz to 250 Hz	31.5 Hz to 125 Hz
1	Idle (in Cab)	80	85.5	83.5	78.5	78.5	74.5	68.5	59.5	49.5	80.5	79.5	79.2	71.9	68.1
2	Full Load Speed (in cab)	88.5	89.5	99.5	91.5	91.5	88.5	85.5	77.5	70.5	93.5	93.7	93.3	86	83.5
3	Idle (Beside)	84.5	80	78.5	78.5	81.5	77.5	72.5	65	55.5	81.5	82.2	82.1	70.4	63.1
4	Full Load Speed (beside)	84	82.5	93.5	94.5	95.5	92.5	88.5	83.5	87.5	96.5	97.4	97.4	86.1	77.5
											Mean	88.2	88	78.6	73.05
											Std. Dev.	8.69	8.73	8.62	9.17

the Drying Building, Flour and Loader (Table 2). For the most part, everything that has been said about the Screening and Grinding Building can be repeated here. Drying Building noise has a sloped curve in two instances: MCC and control room (Fig. 3). Noise attenuation at low frequencies is nominal. The drying and crushing building is also a hazardous source of noise. Gauging the contribution of the drying and crushing building to overall boundary noise can be easily done by stopping work in the screening and grinding building, and vice versa. The flour and loader are insignificant noise sources, but the flour silo airslide blower room has a high noise level (112.5 dBA). Low frequencies are at a low level, which is good because this facilitates attenuation (Table 2). The loader's noise can be lowered by another 5 dBA, but the presence of low frequencies will remain at the same level.

BOUNDARY NOISE SURVEY

Measurements for a boundary noise survey were taken around the Ontario Silica Division in Midland, Ontario. Figure 4 shows the locations at which these measurements were taken. Two of them were made on Manly Street. The noise levels were measured with two sound level meters, one a Type 2, and the other a Type 1. The Type 2 sound level meter was used to measure SPL (Sound Pressure Level), L_{eq} and Peak, and these results are plotted in Fig. 5. The results of No. 19, 20 and 21 are not included in Fig. 2 as they had a different purpose. The SE boundary has the highest noise level. At 100 m from the grinding and screening mill, the noise level was considerably less, 56.3 dBA, but still too high to meet community noise standards. The energy equivalent continuous level (L_{eq}) is a constant sound pressure level (SPL), which has the same energy as time-varying noise for a specified time duration. In this case, L_{eq} and SPL have the same or nearly the same results. Peak or impact, however, is somewhat more understandable. The meter has a rise time of about 20 µsec and drives the peak it finds into an amplifier. The amplifier, in turn, drives

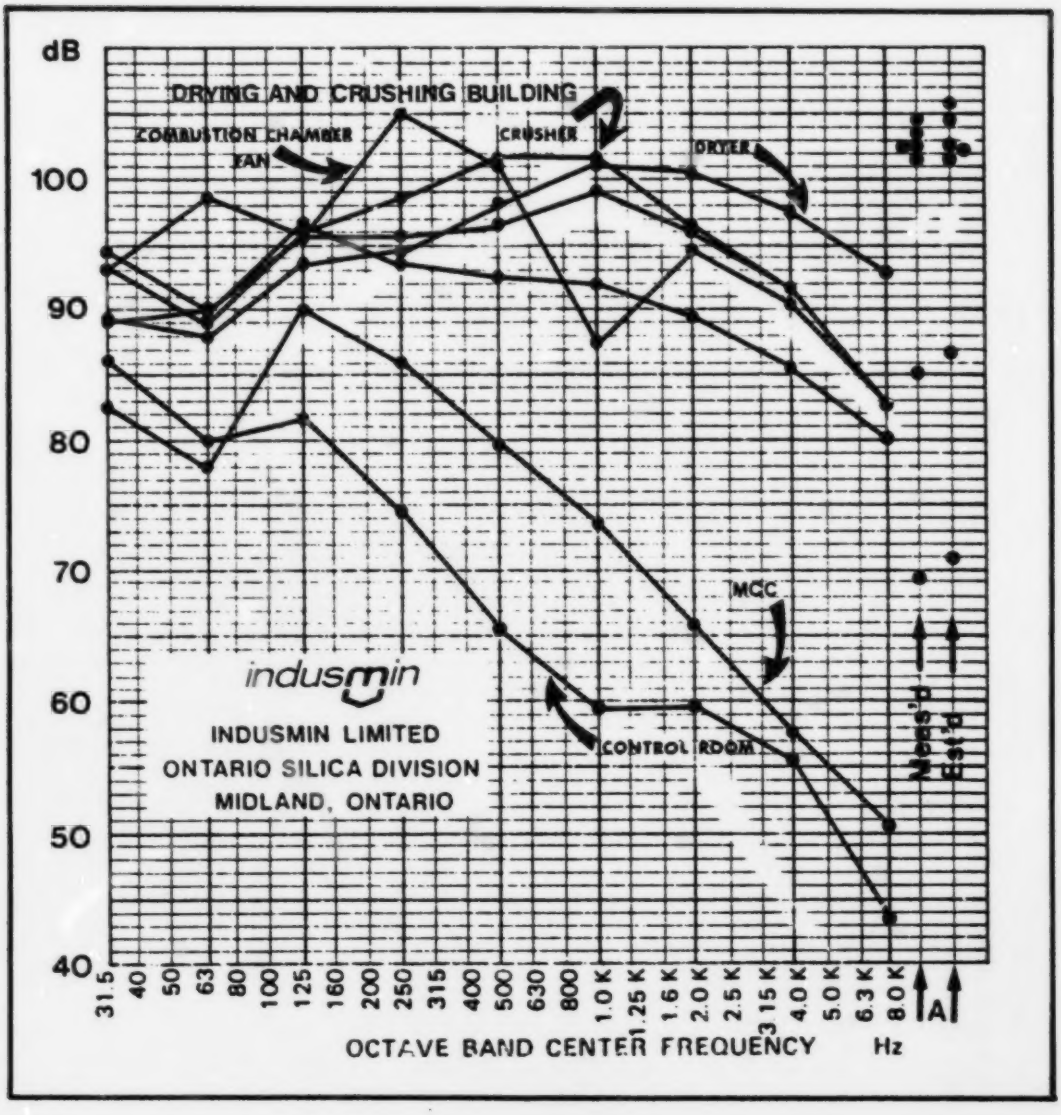


Fig. 3 - Frequency spectrum graph of noise at the drying and crushing building.

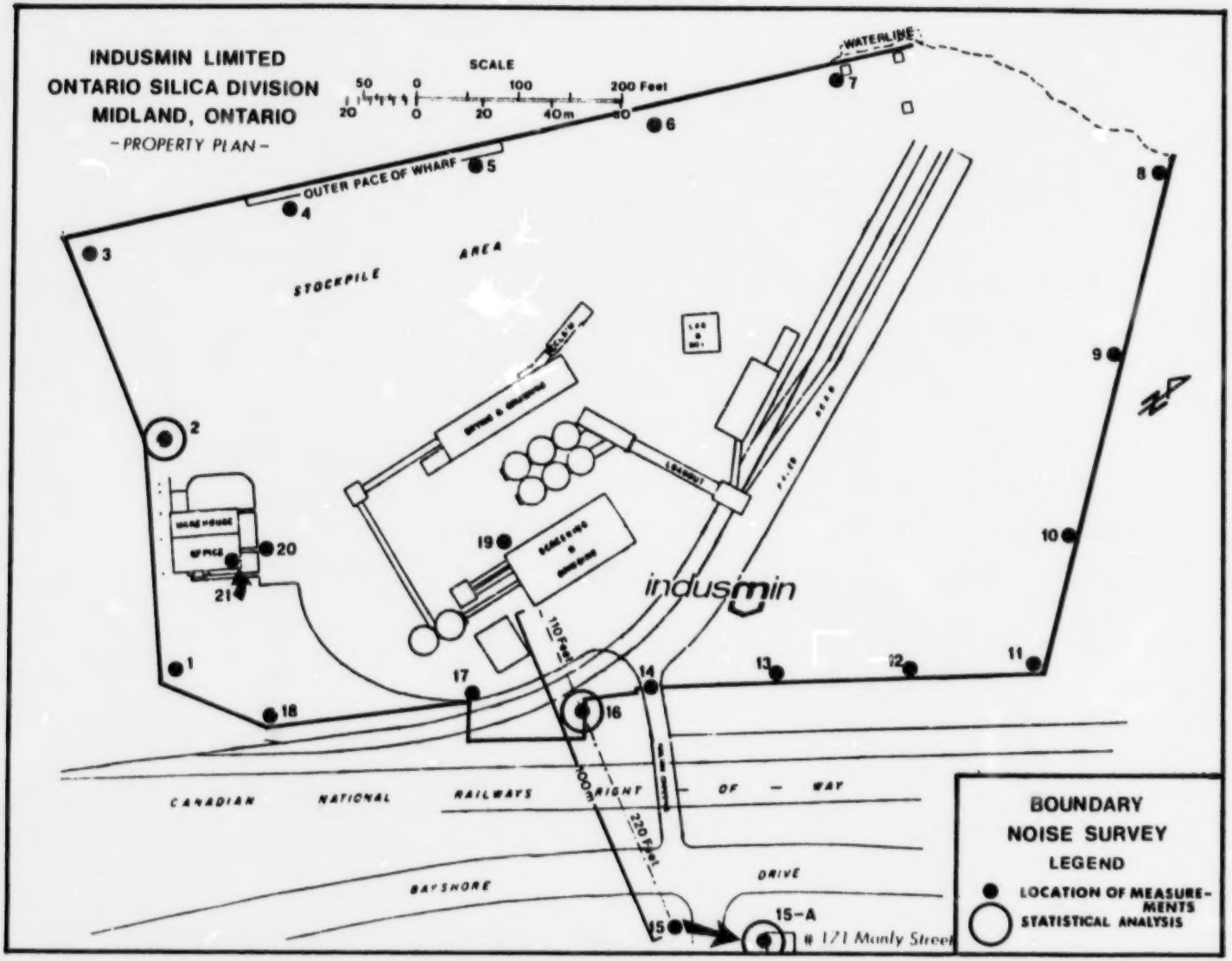


Fig. 4 - Location of the boundary noise survey at Indusmin Ltd., in Midland, Ontario.

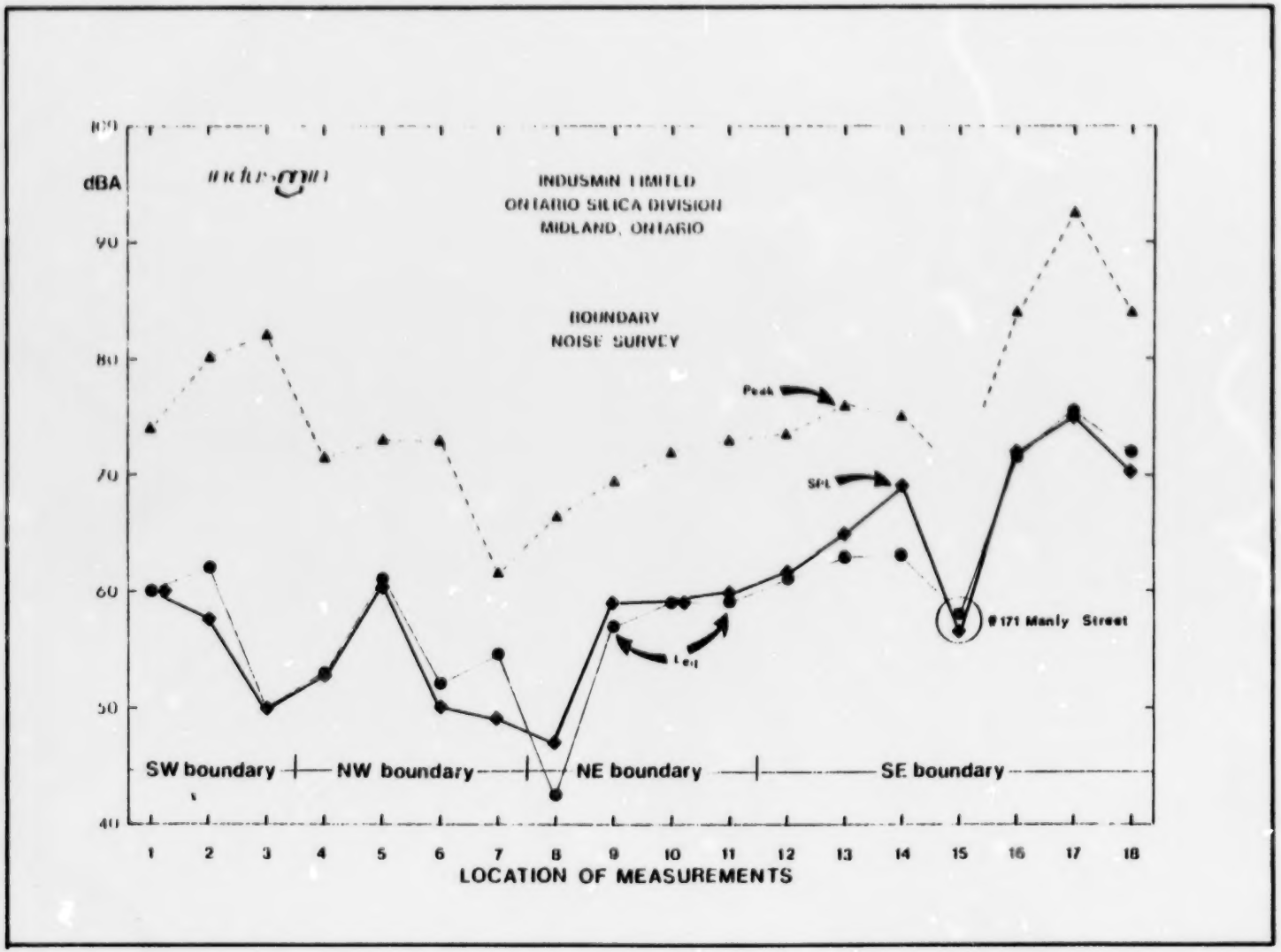


Fig. 5 - Boundary noise survey.

a 'remember' circuit that tells us when the peak is reached. Peak noise is highest on SE and SW boundaries. The cause of this increase is the primary mill, on the southern side of the screening and grinding building. Furthermore, the lowest noise level is on a part of the NW and NE boundaries. At site No. 8, the noise level is lowest because the site is furthest away from the mill. The peak level is relatively high, and this can be explained by taking the noise sources outside the boundary into account.

Frequency analyses were carried out using the Type 1 sound level meter. Table 3 contains the results of these measurements. dBA was estimated from the spectrum level and was then compared with dBA measured. At sites No. 4, 7 and 8 no agreement was found between measured and estimated dBA. This is due to the effect of harbour noise. By the same token, dBA measured and estimated did not agree at sites No. 13 and 14 because of traffic noise. In this Table, the following calculations based on frequency measurements were carried out:

1. dBA evaluation over frequencies of 31.5 Hz to 125 Hz; which have a minor bearing on the final result;
2. dBA evaluation over frequencies of 31.5 Hz to 250 Hz; which have a major bearing on the final result; and
3. dBA evaluation over frequencies of 250 Hz to 8 kHz; which also have a major bearing on the final result.

Noise measurements were taken at site No. 4 on two separate occasions, on the 29th and 30th August, 1983 (Fig. 6). Both occasions yielded similar results. However, the difference between dBA measured and estimated was larger on 29th August. Reasons for this difference have already been discussed. As is evident from Fig. 7, each site has its own peculiarities. If we compare Fig. 7 with Fig. 2, we can see that low frequencies have 'left' the mill and

Table 3 - Frequency spectrum, sound pressure level peak and L_{eq} of the boundary noise survey at Indusmin Ltd.

Site	Frequency (Hz)									dBA								
	31.5	63	125	250	500	1k	2k	4k	8k	Mean'd	Est'd	250 Hz to 8 kHz	31.5 Hz to 250 Hz	31.5 Hz to 125 Hz	SPL(slow)	SPL(fast)	Peak	L_{eq}
+1	76	72	66.5	57	54.5	53	54	49.5	41	60	60	59.1	53.4	52	60	60	74	60
+2	74	72	65.5	58	53	51.5	50	45	38	57.5	57.9	56.9	51.3	51.2	59	58	80	62
+3	70	66.5	60	51.5	44	42	40	37	28	49.5	50.1	48.2	47.4	45.8	52	50	82	50
+4	64	63	65	52	49	41	37	31	27	52.5	52.2	49.1	50.2	49.3	50.5	50.5	71.5	53
*4	64.5	61	68	51	44	40.5	33	34	37	49	53.3	46.9	52.5	52.1				
*5	80	79	71	61	58	52	48	45	38.5	60	61.1	58.8	58.4	57.2	63.5	60	77	61
*6	67	64	60	51	47	43	35	21	27	50	49.9	48.1	46.8	45.1	50	51	73	52
*7	67	64	59	50	43	39	34	28	25	50	47.9	45.4	46	44.1	51.5	51.5	61.5	54.5
*8	62	61	55	50	37	35	29	24	24	49	44.9	42.9	43.8	40.5	46.5	54	66.5	42.5
*9	72	70	64	62	54	53.5	48	43	35	59	58.7	58.2	54.6	49.6	57.5	57.5	69.5	57
*10	74	68.5	61	62	54	53	51	48	39	59	59.1	58.8	54	47.2	59.5	58.5	72	59
*11	72.5	71	62	59	54	54	52	50	46	60	59.6	59.2	52.4	48.7	59.5	58.5	73	59
*12	74.5	70	65.5	59	58	57	53	49	46	61.5	61.8	61.4	53.4	50.7	60.5	60.5	73.5	61
*13	80	74	71	61	60.5	58	52	49	44	67	63.1	62.2	57.4	55.9	63	62.5	76	63
+14	90.5	83	79	73	69	63	57	53	44.5	67	70.8	69.7	67.5	64	63	62.5	75	63
+15	76	72	67	57	47	47	46	45	41	56.5	55.7	53.8	53.7	52.1	-	-	-	58
*15-A	71	70	66.5	59	48	49	45	41	35	56	56.1	54.3	53.8	51.4	-	-	-	57.8
+16	92	85	79	71	69	66.5	62.5	57	50.5	72	72	71.1	66.6	64.8	71.5	71.5	84	71.5
+17	92	88	81.5	75	73	68.5	65	60.5	50.5	75	75	74.2	69.7	67.3	75	75	87.5	75.5
+18	84.5	84	78	71.5	64.5	64	63	59.5	50	70	70.7	69.7	66.5	64	70.5	71	84	72
o19	92	89	85	81.5	80.5	79.5	79	76	68.5	85	85.2	80.1	74.5	70.1	85.5	85.5	98	86.5
o20	84	77	75	70	67	61	61.5	57	49.5	69	69.9	69.5	63.4	59.8	69.2	-	-	69.7
o21	53	55	48	43	35	28.5	25	21.5	23	19.5	39	37.4	36.9	33.8	39	-	-	39.1
SE Corner Manly Gloucester	71	66.5	61	53	47	43	43	40	33	51.5	51.9	50.4	48.4	46.5	-	-	-	53.2
										Mean	60.68	58.99	56.31	53.79				
										Std. Dev.	9.9	10.13	8.3	8.09				

Note: + Aug. 29, 1983; * Aug. 30, 1983; o Aug. 31, 1983

Disagreement between dBA and frequency measurements.

|| Not estimated.

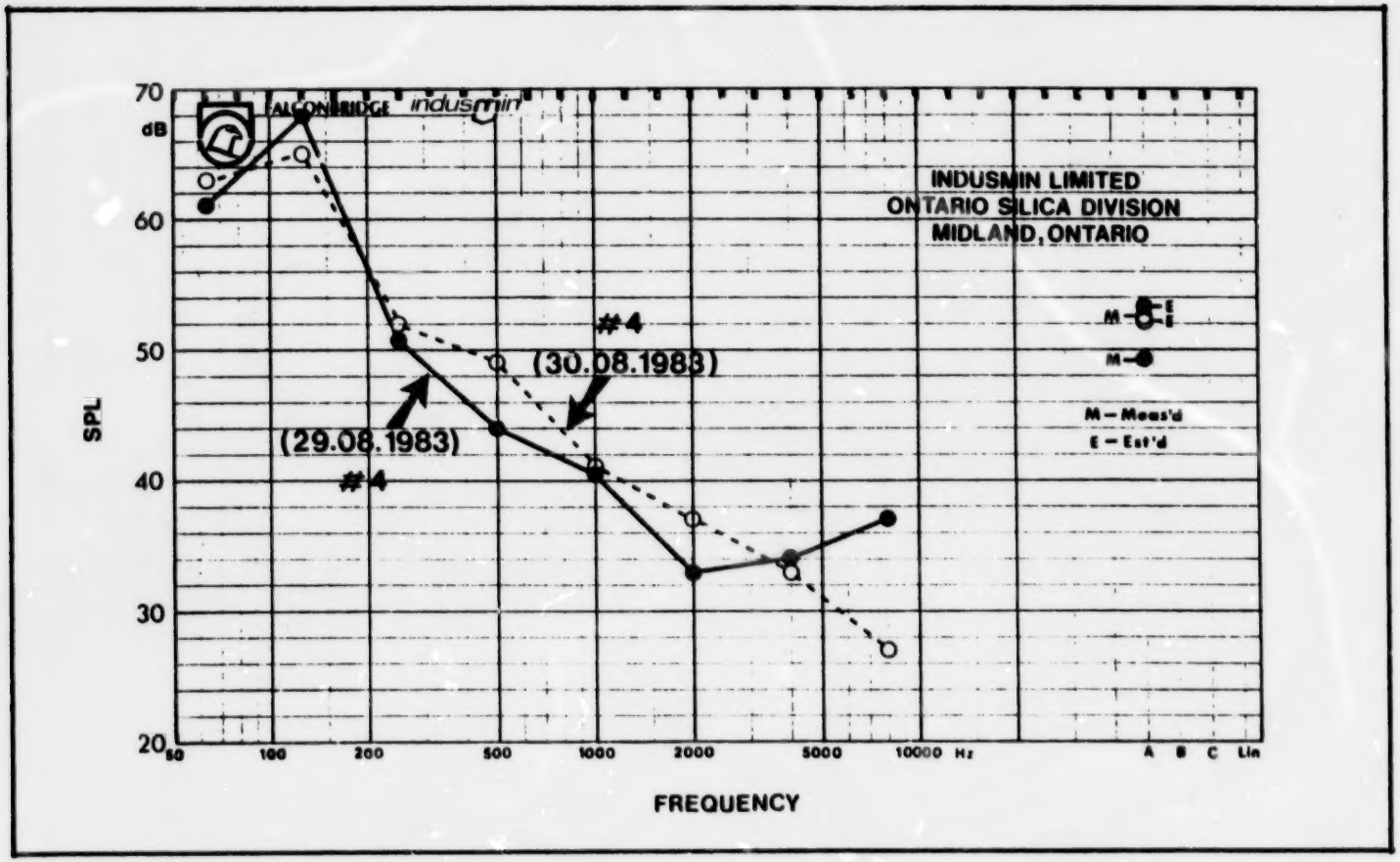


Fig. 6 - Frequency measurements at site No. 4 taken on two separate days, 29th and 30th August, 1983.

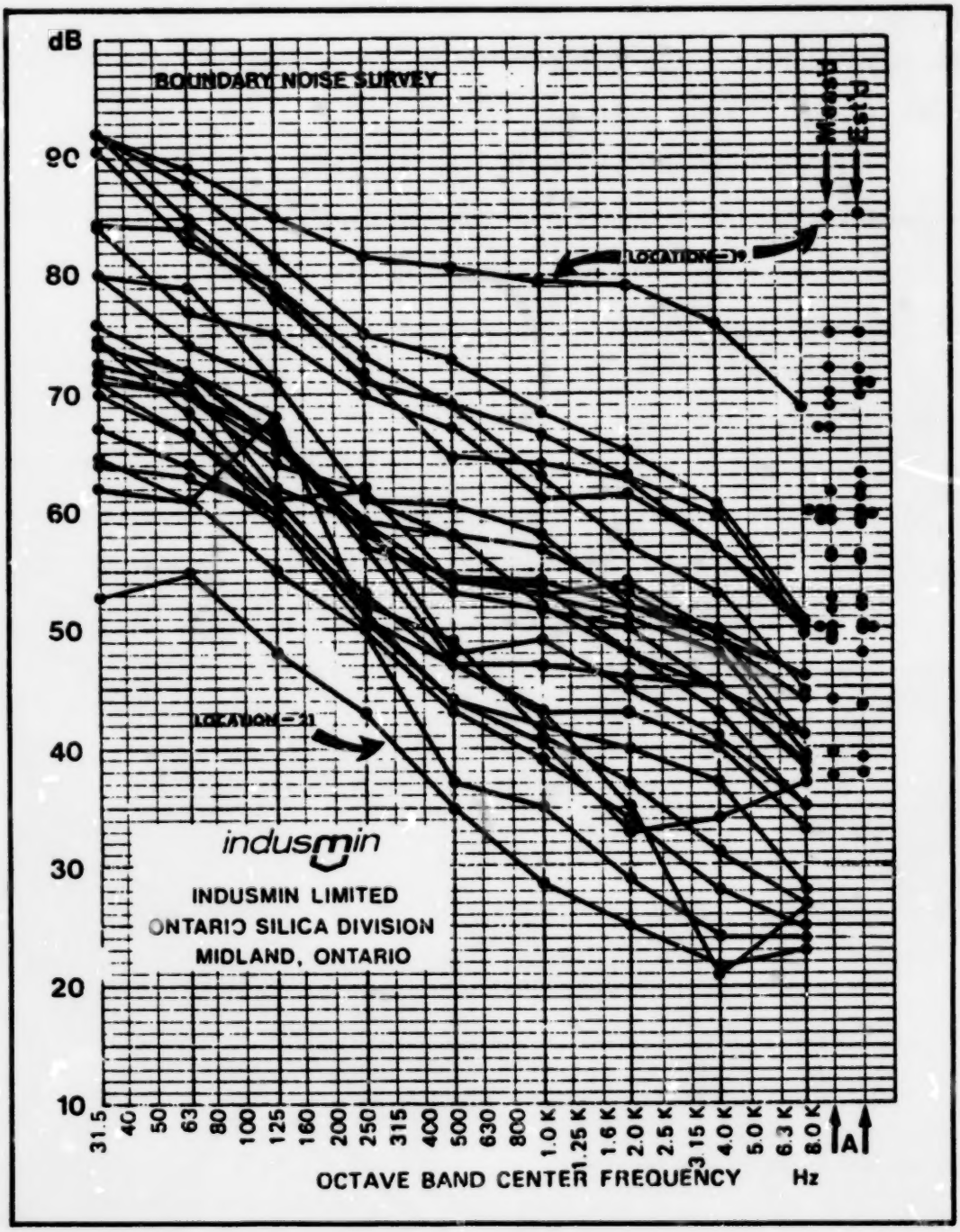


Fig. 7 - Frequency spectrum graph of boundary noise.

have retained their relatively high values. Because of this the frequency spectra in Fig. 6 have a downward slope line.

For a better understanding of the entire problem, a profile of Indusmin Ltd, Manly St., has been constructed in Fig. 8. In this profile, SPL, L_{eq} and distances from the mill are given. To facilitate commenting on this profile, an introduction to the concept of a free field is in order.

A free sound field is defined as a homogeneous, isotropic medium, free of boundaries. In practice it is a field in which the effects of the boundaries are negligible over the region of interest. A free field emits sound uniformly in all directions. The intensity of sound decreases with the square of the distance from the noise source. If the distance is doubled, the sound energy spreads over four times the area and the intensity is one fourth of its original value. This is called the 'inverse square law'.

The sound pressure level, in decibels, is $dB = 20 \log \frac{P}{2.0 \times 10^{-5}}$

Let the sound pressure be P_1 at distance L_1, and P_2 at distance L_2,

then: $$P_2 = P_1 \frac{L_1}{L_2} \qquad \text{Eq 1}$$

Since sound pressure decreases inversely with distance, therefore,

$$dB_2 = 20 \log \frac{P_2}{2.0 \times 10^{-5}} = 20 \log \frac{P_2 L_1}{2.0 \times 10^{-5} L_2} \qquad \text{Eq 2}$$

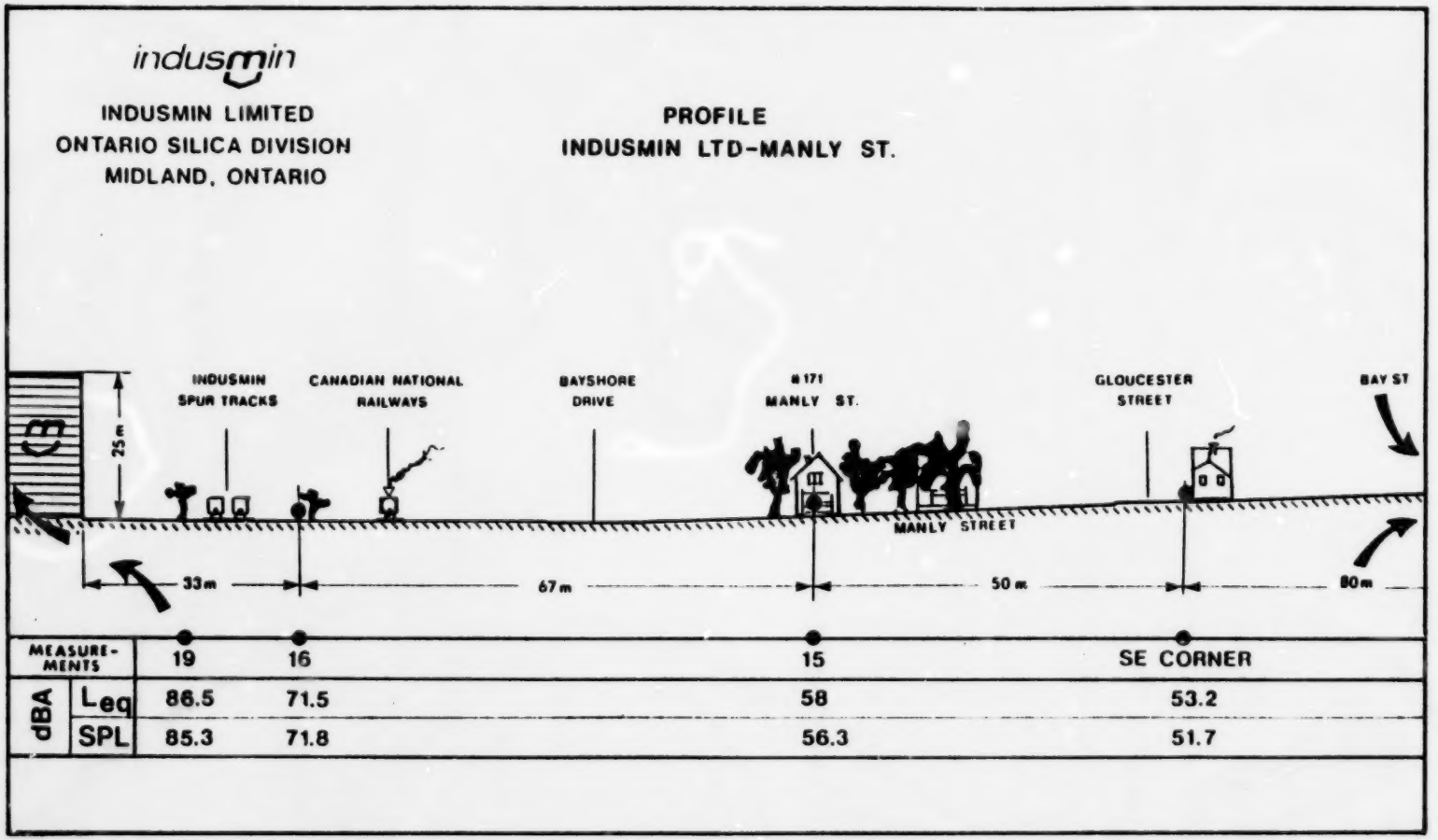
The difference in decibel levels between locations 1 and 2 is:

$$dB_1 - dB_2 = 20 \log \frac{P_1}{2.0 \times 10^{-5}} - 20 \log \frac{P_2 L_1}{2.0 \times 10^{-5} L_2} = 20 \log \frac{L_2}{L_1} \qquad \text{Eq 3}$$

The equation can be written as:

$$dB_2 = dB_1 - 20 \log \frac{L_2}{L_1}$$

If the distance from the microphone to the noise source is doubled, that is, if $L_2 = 2L_1$, then $-20 \log 2 = -6$ dB. This means that the sound pressure level



MEASUREMENTS		19	16	15	SE CORNER
dBA	Leq	86.5	71.5	58	53.2
	SPL	85.3	71.8	56.3	51.7

Fig. 8 - Profile of Indusmin Ltd., Manly Street.

decreases 6 dB each time the distance from the noise source is doubled.

If we now look at Fig. 7, we can see that the decrease in noise is greater than that predicted by the inverse square law. The first decrease in noise is 15 dBA (calculated according to Leq); the second decrease is 13.5 dBA; and the third decrease is 4.8 dBA. This looks good for Indusmin Ltd., because at a distance of 150 m, on Gloucester Street, the total decrease in noise is 33.3 dBA. These measurements should be repeated often so that a mean value can be determined.

ENVIRONMENTAL NOISE SURVEY

In conjunction with these measurements, a statistical analysis was used for three of the measurements, which are related to environmental noise (Fig. 4):

1. Because the harbour is a tourist area, noise at site No. 2 (location of measurement) was monitored during the first shift, from 08:00 to 16:00 hours (Fig. 9).
2. At site No. 16 (location of measurement), noise which penetrates the surrounding populated area was monitored during the second shift, from 18:00 to 06:00 hours the following day (Fig. 9).
3. At site No. 15-A, 171 Manly Street, at a bedroom window facing Indusmin Ltd., for an entire night (Fig. 10).

From the histogram in Fig. 11 one can determine the sound level that is exceeded (a) 10% of the time; (b) 50% of the time; and (c) 90% of the time. Refer to Fig. 11 and read the following from the histogram using the probability-of-exceedance curve.

At site No. 2 (location of measurement) the results are:

a) $L_{10} \approx 60.5$ dBA, exceeded 10% of the time;

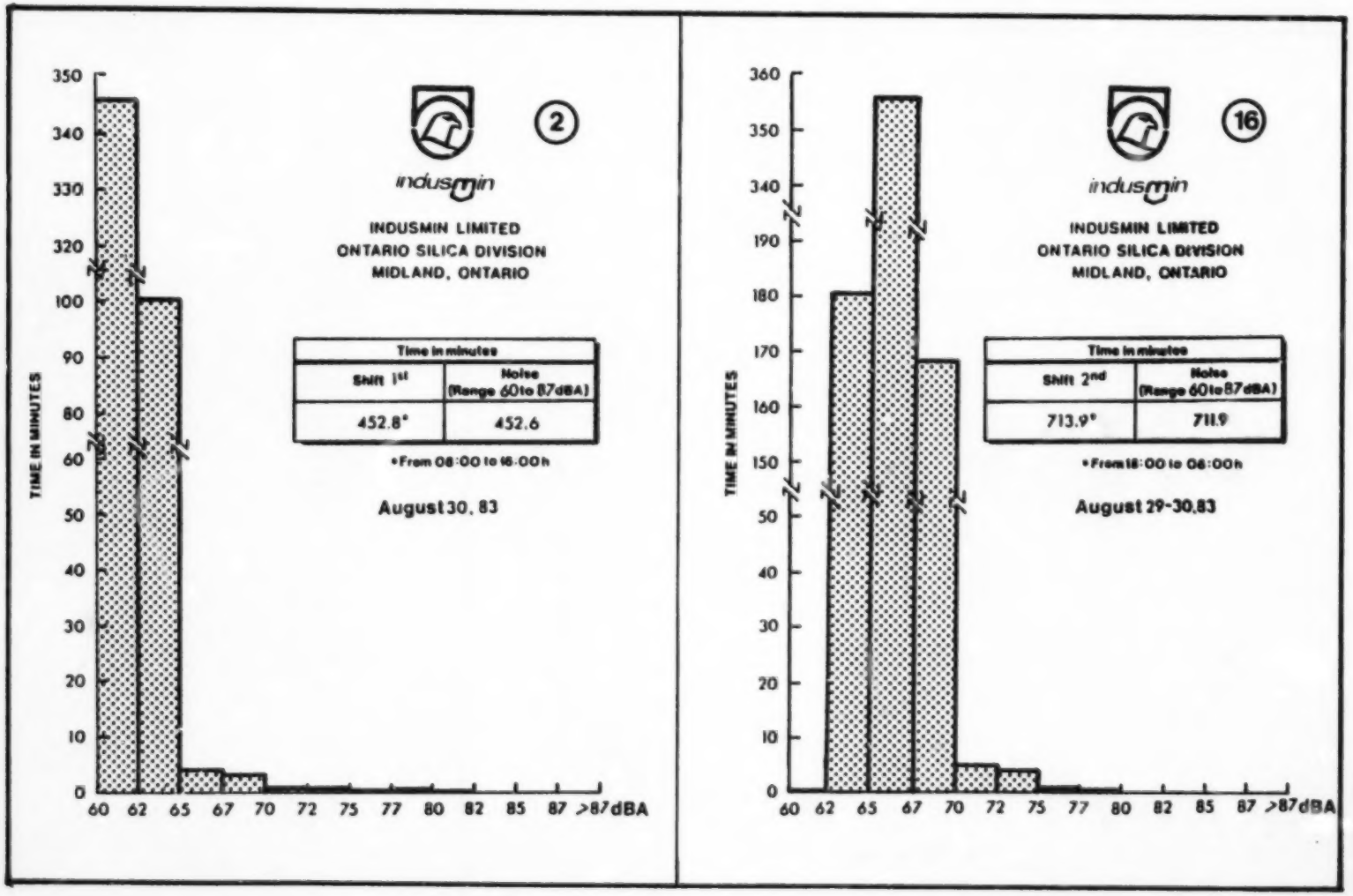


Fig. 9 - Histogram of plant noise at a particular property boundary (see Fig. 4).

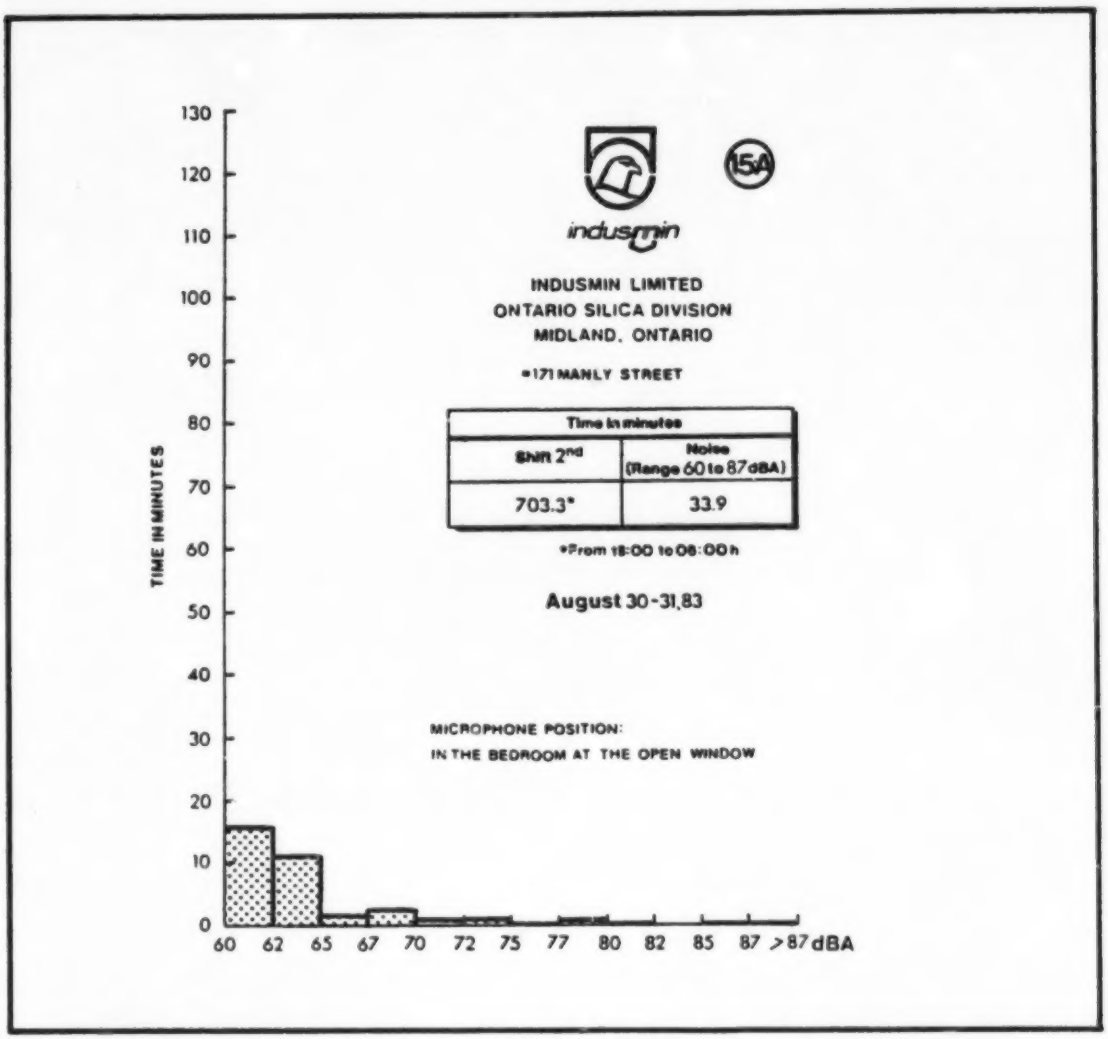


Fig. 10 - Statistical analysis of noise in a bedroom at 171 Manly Street during an entire night (see Fig. 4).

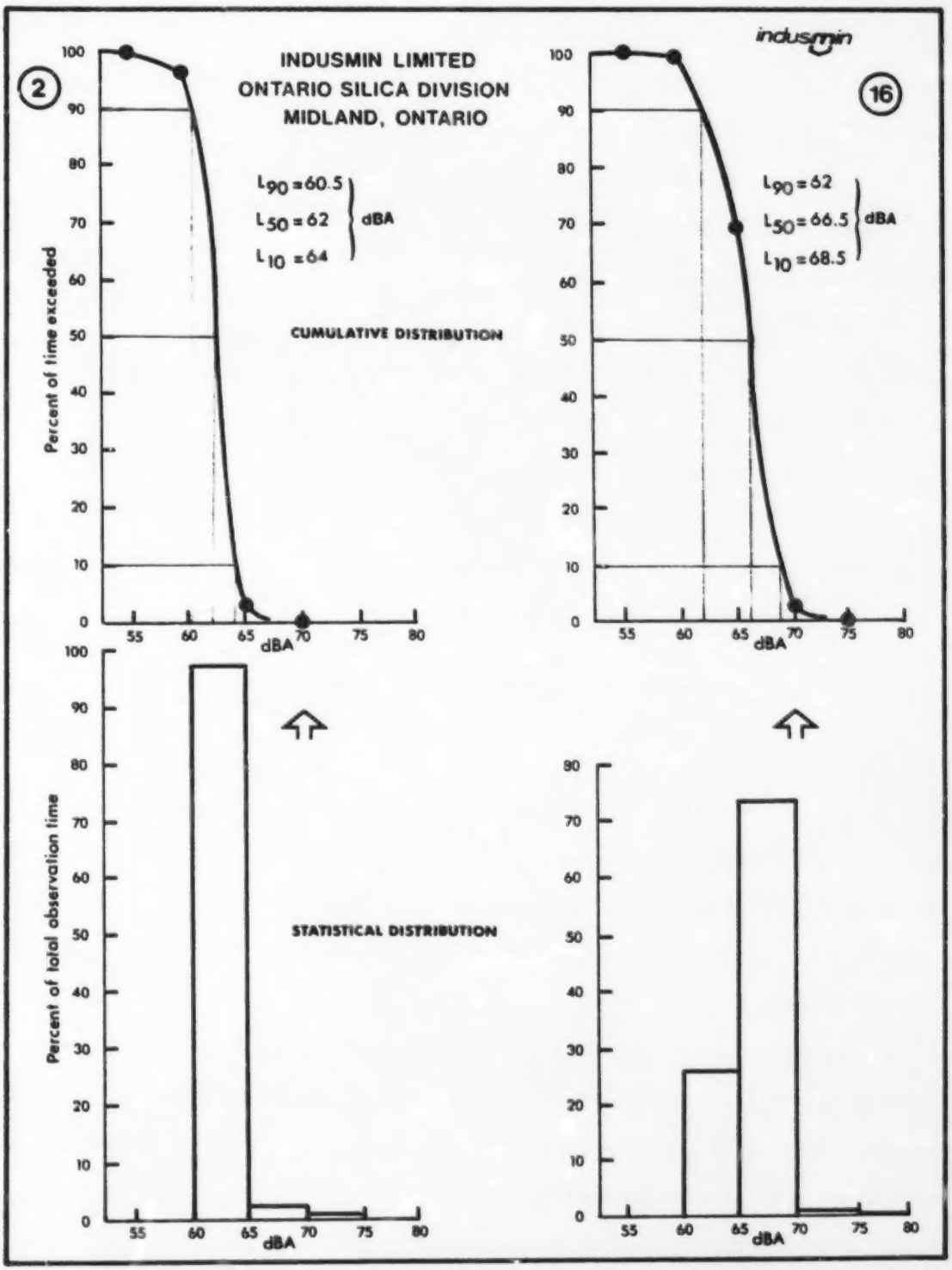


Fig. 11 - Histogram and cumulative distribution function, and data tabulated using the probability of exceedance curve.

b) $L_{50} \approx 62$ dBA, exceeded 50% of the time;

c) $L_{90} \approx 90$ dBA, exceeded 90% of the time.

From the bar-graph portion of the histogram the amplitude band 60 to 65 dBA was recorded for 96.5% of the observation time.

At site No. 16 (location of measurement) the results are:

a) $L_{10} \approx 62$ dBA, exceeded 10% of the time;

b) $L_{50} \approx 66.5$ dBA, exceeded 50% of the time;

c) $L_{90} \approx 68.5$ dBA, exceeded 90% of the time.

From the bar-graph portion of the histogram the amplitude band 65 to 70 dBA was recorded for 73% of observation time.

Because both measurements were carried out indoors to find the environmental sound level, 5 dBA should be deducted from the 50th percentile sound level (L_{50}), or the equivalent sound level (L_{eq}) (5). This was done here:

Site No.	L_{50}	dBA Correction Factor	L_{50} (Est'd)
2	62	-5	57
16	66.5	-5	61.5
		Mean	59.25

This result is good because, over a radius of 100 m, it provides an almost equal value for sound pressure level and equivalent sound level (L_{eq}) at 171 Manly Street. In August 1978, the Ontario Ministry of the Environment introduced permissible outdoor sound level limits (Table 4). From Table 4-A-B-C it is clear that noise levels around Indusmin's plant are high. Noise measurements carried out at the residence, 171 Manly Street, have not provided complete results because the instrument used had a base line of 60 dBA, but even these small indications of measurements in Fig. 10 prove that the noise level will be very high, between 40 dBA and 60 dBA.

Table 4-A - Indoor sound level limits (5)

Type of Space	Equivalent Sound Level (L_{eq}), dBA
Bedrooms, sleeping quarters, hospitals, etc. (Time period 23:00 to 07:00 hours)	40
Living rooms, hotels, motels, etc. (Time period 07:00 to 23:00 hours)	45
Individual or semi-private offices, small conference rooms, reading rooms, classrooms, etc. (Time period 07:00 to 23:00 hours)	45
General offices, reception areas, retail shops and stores, etc. (Time period 07:00 to 23:00 hours)	50

Table 4-B - Sound level limits for outdoor recreational areas (07:00 to 23:00 hours) (5)

Sound Descriptor for the Entire Period	Sound Level Limit dBA
L_{50}	52
L_{eq}	55

Table 4-C - Sound level limits for outdoor areas (23:00 to 07:00 hours) (5)

Sound Descriptor for the Entire Period	Sound Level Limit dBA
L_{50}	47
L_{eq}	50

OFFICE NOISE MEASUREMENTS

Noise measurements in octave band were taken outside and inside the office, 30 cm away from its window (Fig. 4 and 12). These measurements were repeated many times to arrive at the best possible results. They are crucial in showing us possible ways to provide protection against plant noise and protection for surrounding populated areas. For this experiment a safety office whose window faces the plant was chosen. Results have shown that transmission loss (TL) at the 'double window' is around 30 dBA, which agrees with results offered in the literature.

Each band pressure level was plotted on the Noise Criteria (NC) curves and Preferred Noise Criteria (PNC) curves of Fig. 13. The point of highest penetration determines the rating in each case. We find that the spectrum penetrates the NC-30 curve at 250 Hz and exceeds it by about 2.5 dB. This yields an NC rating of NC-45.5. Similarly, we find that the spectrum lands on the PNC-35 at 63 Hz. Thus, the PNC rating is PNC-35. Recommended noise criteria ranges for steady background noise in certain indoor areas are listed in Table 5.

Table 5 - Recommended noise criteria ranges for steady indoor background noise (8)

	NC Curve	PNC Curve
1. Sleeping quarters	25-35	25-40
2. Living quarters	35-45	30-40
3. Office or classroom	30-35	30-40
4. Recording studio	10-20	10-20
5. Retail store or restaurant	35-50	35-45
6. Engineering laboratory	40-45	40-50
7. Computer areas	45-60	45-55

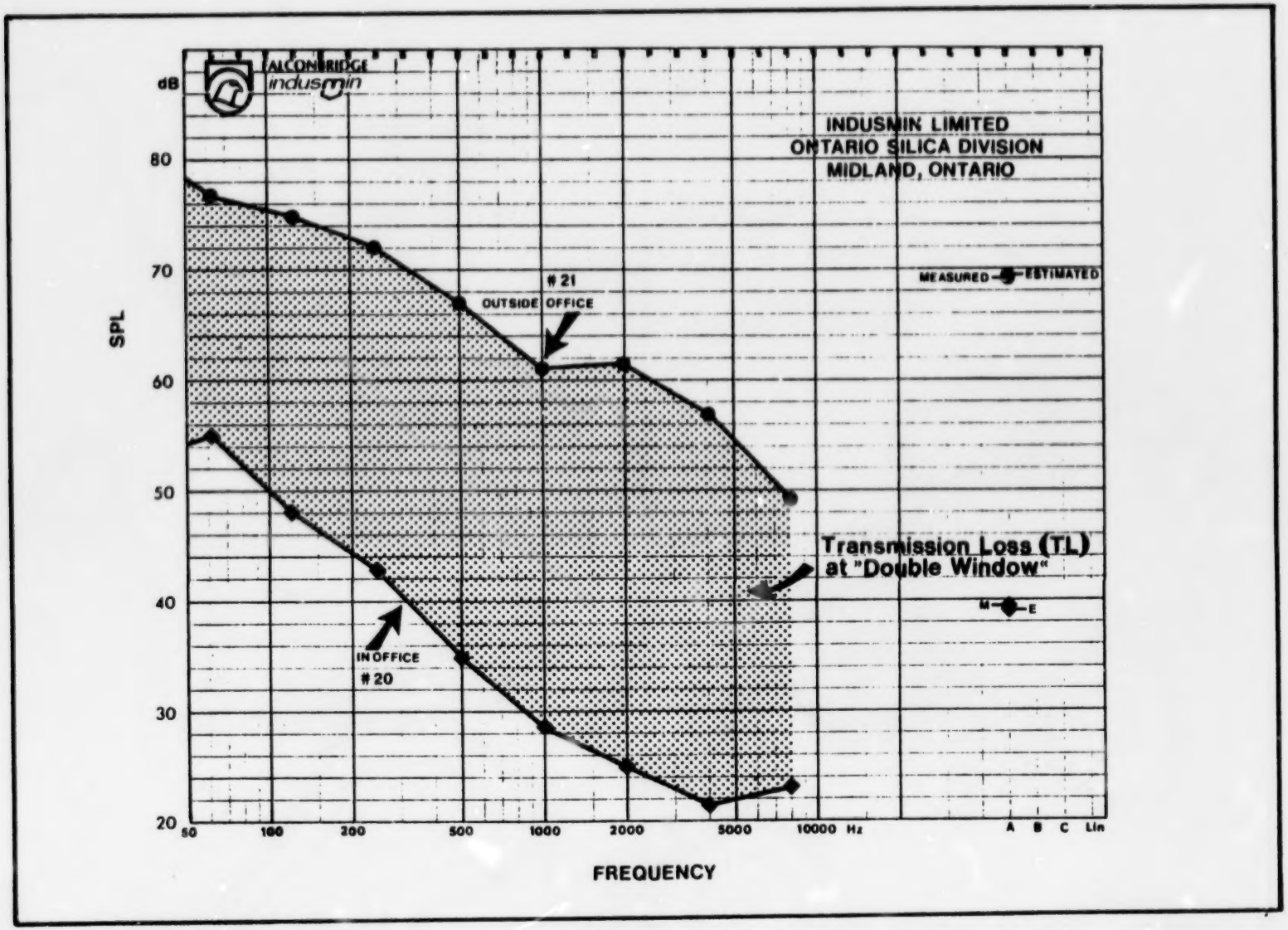


Fig. 12 - Noise measurements outside and inside the office at Indusmin Ltd.

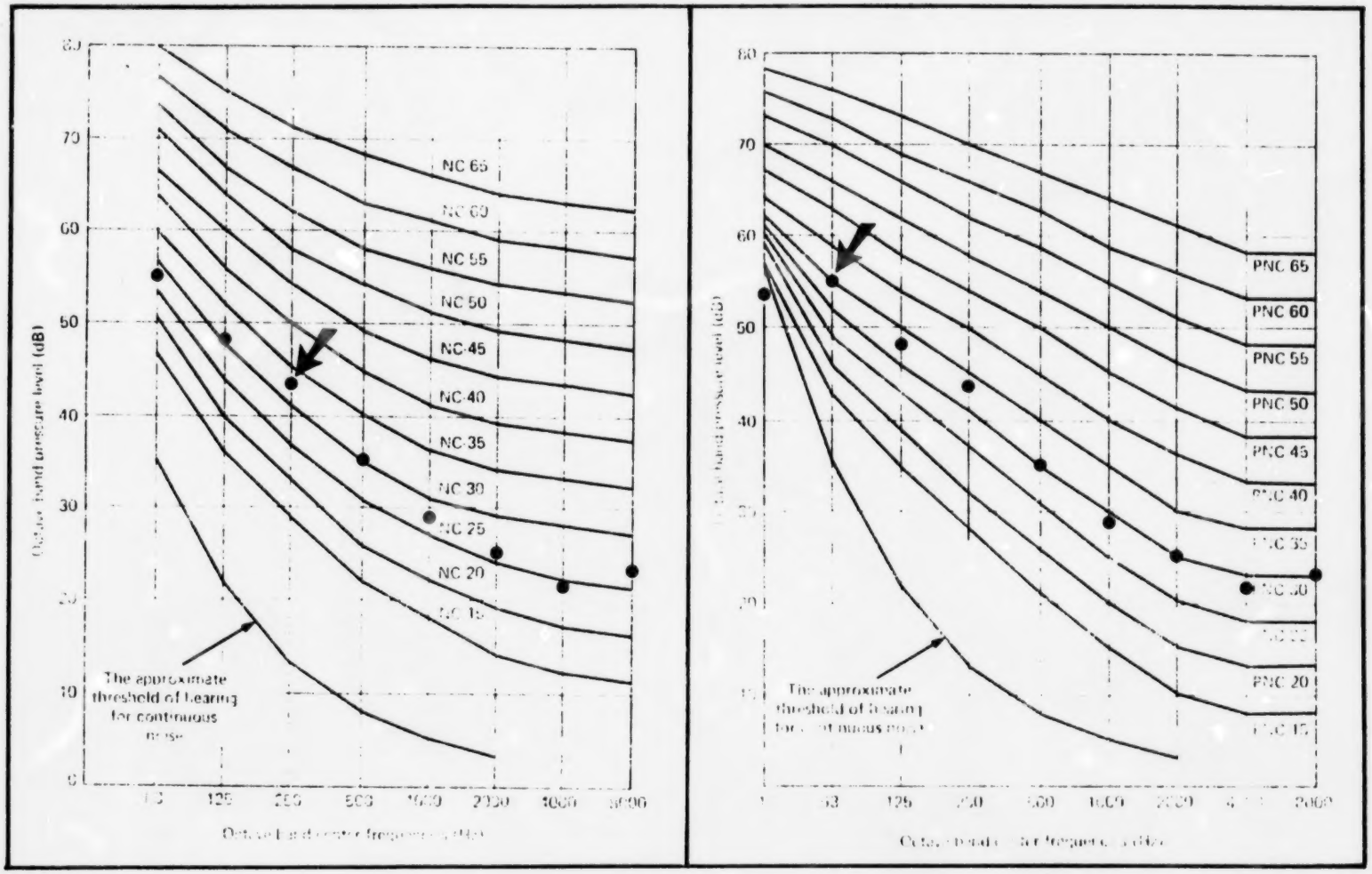


Fig. 13 - Methods of rating the background noise level in a room: use 1957 Noise Criteria (NC) (6,7), and 1971 Preferred Noise Criteria (PNC) curves (7).

Judging from Table 5 it is clear in which category the background noise in Indusmin's safety office belongs.

SOLUTION TO PROBLEMS OF ENVIRONMENTAL NOISE AT INDUSMIN LTD.

Analyses show that the main source of noise at Indusmin Ltd. is the primary mill room (Fig. 2, Table 1). Moreover, many machines produce a high noise level and insulating them would be impossible because of the limited amount of space. It would be necessary, therefore, to insulate the entire space or room. Decreasing noise to a satisfactory level could be done by implementing the design proposed in Fig. 14.

The mill is 36 m long, 16 m wide and 25 m high. Its external walls have been divided into squares of 3 m, so that measurements from base to roof of the building could be completed in two sections of 3 m in 8 hours. At that rate, measuring the entire frontal wall would take 6 days. Two dB-301 Metrologger instruments would be used. They would be placed 1.5 m from the walls. This distance is arrived at by taking into account a 250 Hz wavelength at room temperature (21.1°C) and the velocity of sound in air (344 m/s).

$$\lambda = \frac{C}{f} = \frac{344}{250} = 1.376 \text{ m at } 250 \text{ Hz}$$

where, λ = wavelength; C = velocity of propagation; f = frequency.

For a frequency of 125 Hz, this distance would be 2.752. All frequencies between 250 Hz and 8 kHz would register in the A-network, which is sufficient for our design. Measuring two sections of the outer walls (1-2) would take an hour, after which the slider assembly for standard measurement could move on to the next two sections (2-2), etc. Based on these measurements, a noise contour map for the outer walls of the grinding and screening plant could be drawn. This map would show precisely at which spots thicker or thinner insulation is required and the end result would be more efficient

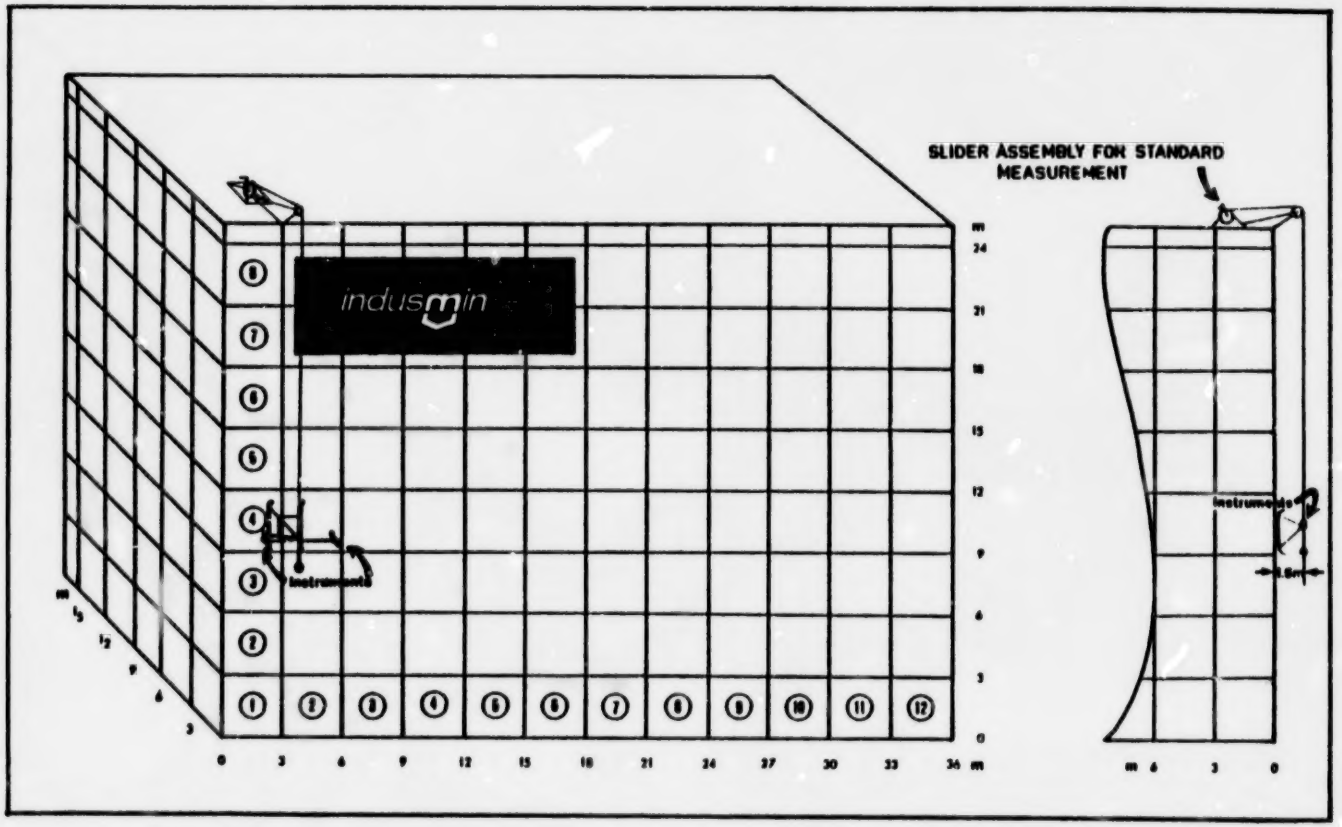


Fig. 14 - Design for decreasing noise at screening and grinding building.

attenuation and less cost. Along with these measurements, eight db-301 Metrologgers would be used to measure noise on the inner walls of the room during a full shift. In this way an adequate picture of both sides of the walls could be formed. The computer program necessary for this method of measuring is already possessed by the Elliot Lake Laboratory. While this project of measuring noise is taking place, all insulation work could be done simultaneously.

Also, along with these measurements, two more measurements of environmental noise will be performed at 171 Manly Street and Gloucester Street, outside the Indusmin boundary. These would confirm either positive or negative results. All evaluations would be made on the spot. The Elliot Lake Laboratory has the necessary computer program for this as well. All measurements would be done with 12 instruments and it would take at least 6 days. Work would be done when the plant is operating nights from 22:00 to 06:00 hours to escape the effects of traffic noise.

There are other methods for this type of measurement, but they require more expensive instruments and more time.

CONCLUSION

The analysis of this case demonstrates that some noise at Indusmin Ltd. can be reduced successfully. Man lives dependent on and surrounded by industries, but industries, nevertheless, should make concessions where they are needed. Therefore, the following is proposed:

1. Indusmin Ltd. should consider implementing the measures described here, or similar ones, as long as they contain the following:
   - integrated measurement of noise inside and around the plant;
   - insulating their plant with either more or less expensive materials,

thus making attenuation efficient while keeping costs at a reasonable level.

2. Indusmin Ltd. should consider enlarging the green belt around its boundaries.
3. City Hall should create a green belt between Indusmin Ltd. and Gloucester Street and ban any residential buildings from it.
4. The key to a solution lies in a close rapport and cooperation between Indusmin Ltd. and City Hall.

Indusmin Ltd., City Hall and the Ontario Government should take into account the following facts:

- Ontario presently needs more silica than it is producing, and an increase in silica production capacity would decrease the amount Canada now imports.
- It is reasonable to expect an increase in production capacity at Midland to take effect in the near future.
- The Midland location is a favourite of Ontario industries, on which thousands of workers depend.

There is no reason why this problem cannot be solved; a solution would only improve the Canadian quality of life.

ACKNOWLEDGEMENTS

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Measurements were performed in accordance with M.A.P.A.O.

REFERENCES

1. Milankowitch, M., Canon of Insulation and the ICE-AGE Problem; Royal Serbian Academy, Special Publication, vol 132, Section of Math. and Nat. Sci., vol 33; Belgrade; 1941. Translated from German by Israel program for Scientific Translations, Jerusalem; 1969.

2. Energy, Mines and Resources Canada; Canadian Mineral Yearbook 1979. 1981.

3. Energy, Mines and Resources Canada; Canadian Mineral Yearbook 1982; 1984.

4. Harding, S.E., "The results of the noise survey"; private communication, June 1977.

5. Ontario Ministry of the Environment, "Model municipal noise control by-law - final report"; August 1978.

6. Beranek, L.L., Noise Reduction; McGraw-Hill Book Co., New York, Chapter 20; 1960.

7. Beranek, L.L., Noise and Vibration Control; McGraw-Hill Book Co., New York; Chapter 18; 1971.

8. Beranek, L.L., Blazier, W.E. and Figwer, J.J., "Preferred noise criterion (PNC) curves and their application to rooms"; J Acoust Soc Amer, vol 50, No. 5, pp 1223-1228; November 1971.